Materials Considerations for Rapid Charging

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Electrochemical Energy Storage Technologies

- **Charging** > 30 miles/min: ➡ "6 C" rate, if total battery pack lasts for ~ 300 miles
  "20 C" rate, if ~ 100 miles
  "60 C" rate, if ~ 30 miles

- **General Challenge**: high current ⬌ heating ➡ losses & degradation

- **Solutions**:

Efficient Cooling

- Cooling (heat dissipation) reduces degradation, but not losses
- The proper cooling should be LOCAL (within the electrode) because nearly all degradation phenomena are thermally activated and local

vs.

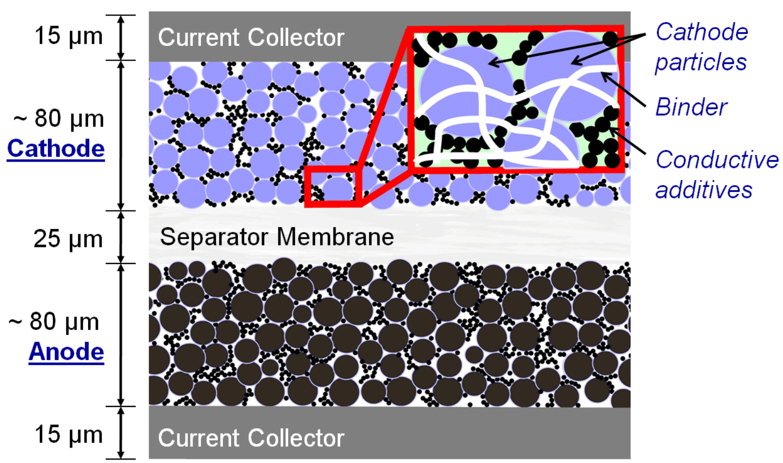
Low Resistance

- Minimizes degradation & losses
- Resistance faced by ions
  - in electrolyte
  - within active particles
  - through SEI *(for batteries)*
- Resistance faced by electrons

Electrochemical Energy Storage Technologies

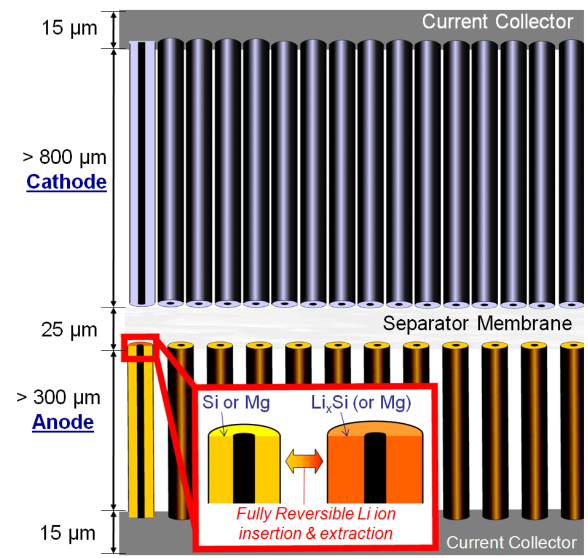
- Rational design of the architecture of battery electrodes allows one to dramatically enhance electrical, ionic and thermal conductivities

Traditional Electrode Architecture:

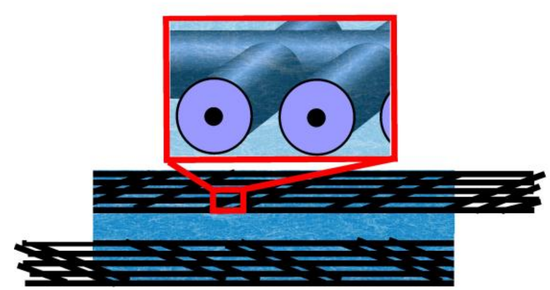


- Low electrical conductivity
- Low thermal conductivity

Alternative Architectures:



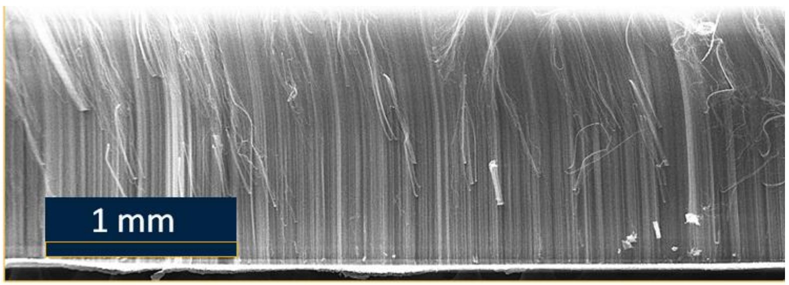
Evanoff, K. et. al, ***Advanced Materials***, 24(4), p. 533, 2011

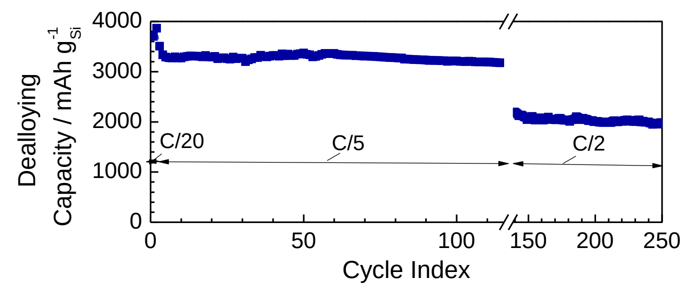


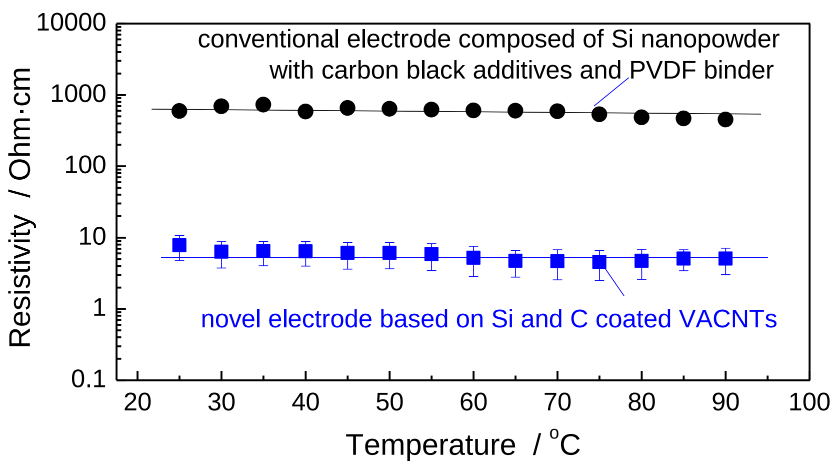
Evanoff, K. et. al, ***Advanced Energy Materials***, *(in review)* 2012

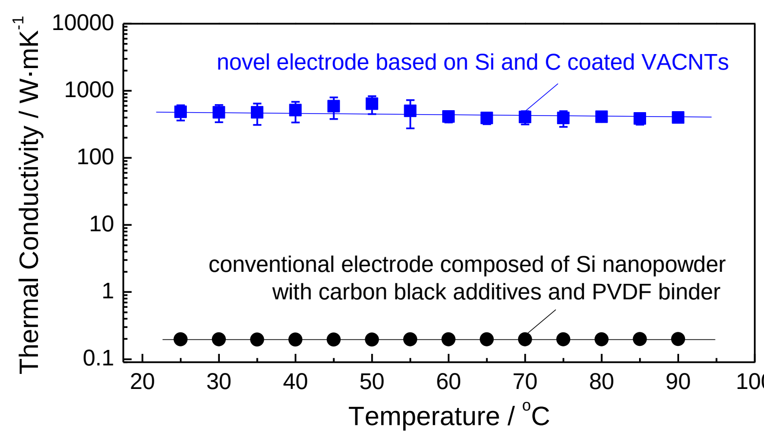
Electrochemical Energy Storage Technologies

- Rational design of the architecture of battery electrodes allows one to dramatically enhance electrical, ionic and thermal conductivities









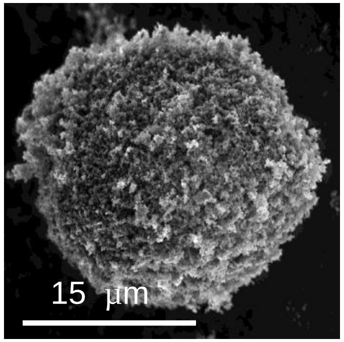
✓ <u>> 100 times lower electrical resistance</u> than that of nanopowder electrode with much higher density but comparable thickness

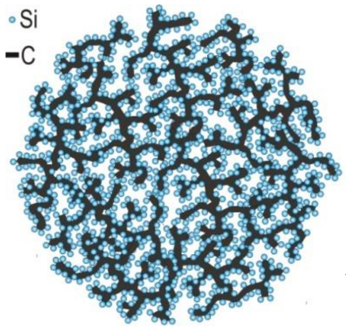
✓ <u>> 1000 times higher thermal conductivity</u> as compared to nanopowder electrode with much higher density but comparable thickness

Evanoff, K. et. al, ***Advanced Materials***, 24(4), p. 533, 2011

Electrochemical Energy Storage Technologies

- More traditional technology: nanostructured (NOT nano-sized) particles





✓ "self-assembled" carbon scaffold for high thermal and electrical conductivities

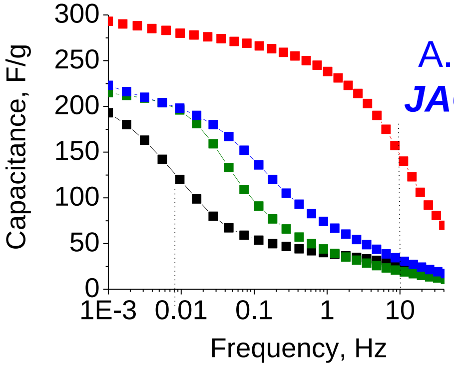
✓ internal pores for rapid electrolyte access

A. Magasinski, et. al, ***Nature Materials***, 2010, *9*, 353

- Fast ion transport within electrolyte possible?

✓ YES, but need to invent <u>novel</u> electrolytes

✓ Supercapacitors (200 um thick electrodes with sub-nm pores) can be charged @ "**30,000 C**" rate



A. Kajdos et. al., ***JACS***, 2010, 132 (1) p. 3252

- Fast ion transport through SEI possible?

✓ YES, but need to invent <u>novel synthetic SEI</u>

✓ As additional benefit – longer cycle life and lower irreversible capacity losses (!)

I. Kovalenko, et. al, ***Science***, 2011, 333 (6052) p. 75-79